Principals of Odorization

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INTRODUCTION

In the one hundred and thirty years, or so that we have known natural gas as a fuel source in the United States, the demand for natural gas has grown at an astounding rate. There is virtually no area of North America that doesn't have natural gas provided as an energy source. The methods of producing, transporting, measuring, and delivering this valuable resource have advanced, and improved in direct relation to the demand for a clean burning and efficient fuel. While today's economic climate determines the rate of growth the gas industry enjoys, in a broad sense, natural gas is certainly considered essential and a fuel of the future.

Of primary importance, in the process of delivering gas for both industrial and public use, is providing for the safety of those who use it. Whether in the home, or workplace, the safety of all who use or live around natural gas systems is of primary concern. Natural gas is a combustible hydrocarbon and its presence may under certain conditions be difficult to determine. One need only to remember the tragic explosion of the school building in New London, Texas in the 1930's to understand the potential for injury when natural gas accidentally ignites. Because of this possibility for accidents, regulations have required the odorization of natural gas when it comes in contact with the population. This enables people living and working around natural gas to detect leaks in concentrations well below the combustible level of the natural gas.

This intent of this paper is to provide basic information regarding the process of odorizing natural gas, which includes characteristics of chemical odorants, typical methods of injecting odorant into natural gas pipelines, and detecting odorant in natural gas. I have sought and used information on areas within this paper dealing with chemical odorants and odorant testing equipment from colleagues whom I consider experts in these fields. You will find them referenced and I urge you to use these references to obtain more information on these critical areas which are so important to the odorization process.

CONSIDERATIONS OF AN ODORANT PROGRAM

Just to say that the odorization program should be implemented to odorize the natural gas is obviously too simplistic. The object of the odorization program is to insure that the natural gas is odorized sufficiently to be readily detectable by a normal sense of smell at one fifth the lower explosive limit of the natural gas. This is a standard which is contained in the ***Code of Federal Regulations Title 49 Part 192.625.***

The lower explosive limit for natural gas in a mixture with air is approximately 5%. Therefore the presence of natural gas must be readily detectable at one fifth of that lower explosive limit or 1% gas in the presence of air.

To meet this standard, there are basic considerations which, when included in the planning and development of a odorization program allows the odorization system to operate at maximum capability and provide a safe natural gas supply. These principal program considerations include;

- Odorant Selection
- System Selection
- Components of the Injection System
- System Performance Audit Trail
- Odorant Level Detection

ODORANT SELECTION AND USE

The selection of the odorant to be injected is an important aspect of total system implementation. Selecting the specific odorant to be injected involves knowledge of the chemical composition of the gas, the physical and chemical characteristics of available odorants, the physical layout of the pipeline system and local storage tank, ambient conditions, the desired odorant level, and the current recognition of smell that the local population has. Sometimes changing odorant may create problems in that the smell may be slightly different than what the population is used to. Always consult the chemical manufacturer when selection or changing the chemical odorant is contemplated.

Odorants which are commonly used today are typically a blend made of the following components;

- Tertiary Butyl Mercaptan or (*TBM*)
- Isopropyl Mercaptan or (*IPM*)
- Normal Propyl Mercaptan or (*NPM)*
- Secondary Butyl Mercaptan or (*SBM)*
- Dimethyl Sulfide (*DMS)*
- Methyl Ethyl Sulfide (*MES*)
- Tetrahydrothiophene (*THT*)

Note that THT is sometimes used by itself as an odorant.

Each of these components have characteristics which when used as a component of an odorant blend in a specific percentage make it suitable for specific applications.

For example a typical odorant blend that is comprised of 75-80% TBM and 20-25% DMS is very suitable for an injection type system because of the characteristics of the components. The characteristics to consider when selecting an odorant or odorant blend include;

- Vapor pressure
- Gassy odor
- Soil penetrability
- Resistance to oxidation

Each manufacturer of chemical odorant has rigid specifications for the chemicals they produce. Consultation with the manufacturer is highly recommended in order to attain the correct chemical for each application.

Critically important to the odorant system is the local delivery of odorant. This is another area that the chemical manufacturers take great care in addressing. It is important that no odorant be released as well as limiting fugitive odor emissions during the fill process. The odorant manufacturer typically has systems onboard the chemical truck to allow for safe delivery of the chemical. For smaller injection applications, odorant can be delivered in transportable containers from which the odorant can be transferred or in some cases the chemical can be injected directly from these containers.

SYSTEM SELECTION

As in any application of equipment, it is essential to select the proper tool for the job. In the odorization process this is an essential step. Generally, odorant systems introduce odorant into the gas stream in two ways.

- Chemical absorption
- Chemical injection

Absorption type systems rely on the diffusion of odorant into a flowing natural gas stream by taking advantage of the chemical characteristics of the odorant vaporizing into the natural gas.

Examples of these type systems are wick type and bypass type systems.

The wick type system can best be compared to a kerosene lantern where the chemical climbs a wick which is inserted in the pipeline and combines with the gas stream as it flows past the wick. These systems are generally applied in very low flow applications and typically have low odorant storage volumes involved with the system.

The bypass system involves a storage tank containing odorant which is connected to the pipeline such that a portion of the flow of the pipeline bypasses through the odorant storage tank and contacts the surface area of the natural gas within the tank. The chemical characteristics of the odorant allow for vaporization of the odorant into the flowing natural gas and the odorized gas flows back through the bypass line back into the main flow stream and mixes with the primary pipeline. These systems are typically applied in low but steady flow volumes.

In applying absorption systems, care should be taken to insure that no contaminants (liquids) enter the system which may inhibit the effect of the odorant on the gas stream, and that the ambient temperature of the odorant remains relatively constant.

The injection type system does not rely on absorption of natural gas as the primary force introducing the chemical into the flowing stream. Rather, the injection system is a positive injection of the odorant which is stored away from the pipeline into the flowing stream. This system is typically used on a wide range of flowrates and the system is sized dependent on the injection size of the injection pump which is a component of the system.

Operation of the injection type system in a properly controlled manner is a necessity. The odorant system should always operate in a proportion-to-flow manner. In flow proportional injection, the odorant system injects chemical in proportion to the flow rate of the natural gas flowing in the pipeline. A ratio between the injected odorant and the flow of natural gas is measured in pounds of injected odorant per million cubic feet of natural gas flow, or lb/MMCF. It is important to remember that the odorizer is not the device determining whether the odor of the natural gas is sufficient to be recognizable at the mandated level. Again this determination is specifically described in the standard mentioned previously and is measured ultimately by the human nose or olfactory system by instruments which to allow a technician to smell and evaluate a sample of the gas stream.

The injection system must have the ability to perform a prescribed injection rate over a range of possible flow rates. This may depend on seasonal temperatures or industrial load. Additionally, the system must be able to operate within a broad range of injection rates. These injection rates may range from .2 lb./MMCF to as much as 3 to 4 lb./MMCF depending on what rate of injection is required to achieve the minimum detectability of the gas.

It is important to devote great care to insure that the system will operate at a desired injection rate throughout the entire range of anticipated flow rates. And because the injection rate must be monitored, the typical injection system should incorporate measurement of the odorant injected.

Because injections systems are mechanical and endure wear, a primary concern has to be system malfunction. Knowing when these repairs are necessary is possible utilizing onboard monitoring and alarm systems which are usually incorporated into system design along with audit trails which automatically record system performance.

The goal of these systems is to operate automatically, to inject the odorant proportionate to the gas flow as prescribed, to account accurately for the odorant injected, to alarm if there is a problem within this process, and to provide a audit history of system performance.

COMPONENTS OF AN INJECTION SYSTEM

While individual designs of injection systems may differ from manufacturer to manufacturer, the basic functions of the system are common to all systems. The components of the typical injection type odorizer are:

- Injection Pump
- Injection Rate Controller
- System Monitoring & Verification
- Alarm System
- Performance Reporting & Audit Trail

The Injection Pump is one of the most important components in the injection system and is usually, but not always, a positive displacement pump. Some systems use differential pressure and the operation of a solenoid to move odorant.

Injection systems utilizing displacement pumps incorporate pump designs which allow for the compatibility of internal seals and working parts of the pump with the chemical characteristics of odorants. Some pump designs process a segregated seal design where the moving parts and critical seals within the pump operate immersed in hydraulic fluid which is totally separated from the chemical odorant. As the pump actuates, the hydraulic fluid is compressed against a diaphragm type seal containing a known volume of odorant. This compression creates a pumping action on the odorant displacing the odorant volume into the pipeline.

Figure 1; Pneumatic Injection Pump

Injection systems using a positive displacement plunger type injection pump usually operate the pump pneumatically. In this way a gas supply is taken from the flow stream, properly regulated and then communicated to the injection system pump for use as an actuation source. When the injection system controller determines that an injection is required the pump plunger is actuated using this pneumatic supply. The volume of each injection can be manually adjusted to increase or decrease the amount of odorant injected with each stroke of the injection pump. It is important that this pneumatic supply is taken from the pipeline upstream of the injection point to avoid nuisance odor as the actuation gas is exhausted.

Figure 2; Injection Pump and Meter

The Injection Rate Controller receives flow rate information from a flow measurement device and, using a microprocessor, automatically calculates the pump injection frequency required to meet a programmed injection rate. The ability to track the flow rate present in the pipeline, and then match an injection frequency with that flow rate is termed flow-proportional injection and as previously mentioned, is the desired method of injection.

To set up the injection rate controller for operation basic information or parameters are entered into the controller program. While detailed system setup parameters can be programmed into the controller, the basic system parameters might include;

1. Injection rate desired *(lb. /MMCF)*
2. Chemical density of the selected odorant (*lbs/gallon*)
3. Pump displacement selected *(cc/pump stroke)*
4. Minimum, maximum and normal flowrates
5. Flow input signal information *(analog/pulse)*

The design of the injection rate controller should allow for a programmed fail safe parameter which would allow for a preset injection rate in the event that the flow signal between the flow measurement device and the injection system is compromised.

Figure 3; Injection Rate Controller

System Monitoring and Verification allows the system to determine the current performance status of the injection system. It is important to note that the capability of monitoring and verification within the system requires measurement of injected odorant. Therefore, the injection system should contain an odorant meter to measure accurately the volume of chemical odorant injected. The method used to meter odorant injected may vary in design from system to system. The system depicted within this paper uses a known volume type meter to determine the amount of odorant injected by the system. This means that a precise known volume of odorant supplies the suction of the injection pump. Monitoring those changes in the level of the odorant caused by displacement of the pump provides measurement of the amount of odorant injected. Systems might also employ positive displacement, or rotating disc type precision meters in this application.

The odorant measurement data is communicated to the injection rate controller and allows for a comparison of the flow input and actual injected volumes, with anticipated data to ascertain if the system is performing properly. The injection rate controller also uses the information from the meter to allow for compensation of injection frequency based on the actual injection volume produced by the pump. As the injection pump volume changes due to wear, the controller changes the injection frequency at the same percentage of the displacement error. The system usually provides alarm capabilities based on pump displacement.

The meter should also have a means of compensating system performance for changes resulting from differences in odorant temperature. The advantages of the known-volume meter are that it has few moving parts, and requires no routine meter re-calibration.

The monitoring system also continuously monitors the condition of other subsystems which effect system performance. These subsystems monitored might include;

- Flow input signal status information
- Power supply information
- Odorant meter status
- Odorant bulk storage tank volume

The system provides means for remote monitoring of the amount of injected odorant and configuration of the system.

Monitoring and verifying system performance is also performed by local indication of performance data. Most injection systems are provided with local display of system performance data for local use.

The Alarm System operates in conjunction with the monitoring system so that malfunction of critical subsystems is communicated and may be reacted to. Upon determination that a problem exists, the system provides an output to communicate the alarm to a remote location. Locally, the alarm is also displayed along with troubleshooting information to assist in isolating the condition creating the alarm and planning proper maintenance procedures.

Performance Reporting and Audit Trails are usually generated with the use of onboard devices which contain an ongoing event log. The onboard memory would be sufficient to contain approximately 90 days of data.

This transferred data may then be reviewed or configured into a report form which provides a detailed overview of the system performance. While this audit and reporting data may be different somewhat depending on the system used, this information would typically contain, odorant usage, alarm conditions, odorant injection rate displayed and reported on a daily and hourly basis. This type information may be critical in evaluating the performance of the odorant system to a specific time, or planning the amount of bulk odorant a station may require as well as schedule a delivery.

ODORANT LEVEL DETECTION

The final component in the odorization process is the testing for odorant intensity throughout the system. Recalling the set standard mentioned previously, the goal is to be able to readily detect the presence of natural gas at one-fifth the explosive limit with a normal sense of smell, it is necessary to physically sample the gas, and using someone with a normal sense of smell, evaluate the sample for detectability.

This process enables those in proximity to gas facilities or those using natural gas to be able to detect leaks and take action to avoid accidents.

The process for conducting test may be a function of state mandates and it is usually required of users to conduct periodic testing of combustible gases to determine the concentration of odorant.

Compliance with these mandates in determining who, what, when, and where testing should be done is up to each company. The user must know what instruments are available for testing and basic guidelines in their application to implement a successful testing process.

TEST INSTRUMENTS

There are three units currently available to do the quantitative olfactory test, commonly called the sniff test: The DTEX made by YZ Systems, the Odorometer made by Bacharach, and the Heath Odorator.

All three units were designed to mix gas and air and move them to a sniffing chamber. The air is drawn in through each unit, and mixed with gas. The technician smells the gas and air mixture, gradually raising the level of gas in the mixture until he or she detects an odor of gas.

The Bacharach Odorometer was the first device designed to monitor odor levels and is still available today. The Odorometer uses a rotometer (balls floating up and down on the air stream created by opening the gas stream). The results of a test are read off of the bottom of the balls and compared to a chart on the unit door prepared for each Odorometer.

To take a test you sniff one inch above the sniff chamber as you open the gas valve until you smell the threshold [slight change]. Record the reading then open the valve until the odor is readily detectable at the sniff chamber. Record the reading and compare it to the calibration chart to get a final result. The unit is calibrated for gas with a specific gravity of 0.62, and calculations must be done if the gas being tested has a different specific gravity. The Odorometer is available in A/C and battery powered models. The Davis/Heath Odortester was the second device manufactured but was discontinued in the early 1980's.

The Heath Odorator was the third unit designed to test for odor intensity. To take a test with this device you must first zero the unit following the instructions printed on the side of the box. Next open the gas valve while positioning your nose above the sniff chamber until the odor intensity reaches the threshold level. Push the display button and copy down the reading. Again with your nose above the sniff chamber, open the valve until the odor intensity reaches a readily detectable level. After the readily detectable level is reached, you push the display button and read the display. Then compare the two display readings to the chart for correction on the side of the unit to get your test results.

The latest unit developed is the YZ Systems DTEX. To take a test with the DTEX the operator turns on the power and the unit puts itself through a series of self-diagnostic checks. After the operator logs on with a private password, he or she can choose to do a test at a pre-entered test location, or a new location can be entered via the keypad on the unit.

Information regarding location would include

- Location name
- City
- State
- Zip Code
- Operator

Each of these, along with actual test data, are recorded and stored in a paperless audit trail and can be used later to look up information for reports or graphing. Altitude is used to compensate for air density, providing more accurate test results. Instructions are displayed on the unit's LCD screen, and they guide the operator through the test sequence including opening the valve to a threshold and readily detectable level of odor intensity. At both levels the operator will push the record button to lock in the readings. When the test is complete the results will be displayed on the unit as well as stored in memory with all other data needed to identify the location and results of that test (date, time, address, test levels, operator, etc.). This information can be viewed on the unit display or downloaded to a computer for storage and future use. The YZ Reporter software enables the operator to preload any test points and save test locations entered in the field for future use. It also has features like graphing and separate operator identification. The DTEX is battery operated and has an Intrinsically Safe rating for use in a hazardous environment.

Regardless of the type of device being used, considerations to assure an accurate sniff test include:

- All units should be calibrated according to the manufacturer's recommendations.
- The operators should be trained and refreshed annually on the operation of the instrument they are using and how to properly take a test.
- Units, hoses, regulators and other accessories should be checked and smelled before taking test.
- Smelly hoses should be replaced.
- Other accessories that smell should be replaced or cleaned to remove smell. Verify units are in good working order.
- Do not over pressure units (see manufactures specs on the unit).
- Do not smoke, eat, or drink 30 minutes prior to taking a test.
- Do not take tests after plunged exposure to odorant (for example after removing a regulator that smells, after filling odorant tanks, etc.).

Figure 4; Sniff Testing Devices

TEST LOCATIONS AND FREQUENCY

There is no set frequency but you should test often and at regular intervals. Also consider mixing in testing from other departments on their rounds throughout the gas system including each city and town in that system. This is a case where more is better. You want to get the big picture.

Taking a test out in the open such as at town border stations and regulator stations is not recommended. There are several reasons to avoid test at locations like these; extreme temperature changes, wind, possible leaks, to mention a few. All of these things can alter your test readings, as referenced in ASTM D 6273, Standard Test Methods for Natural Gas Odor Intensity.

Recommended places to test are facilities that are manned 24 hours a day so usage is enough to have fresh gas, thus giving a better picture of the system at that time. City and government buildings such as

- Fire stations
- Police departments
- Post Offices
- Schools
- Gas Company Service Buildings
- Military Bases

Good test points would include water heaters and stoves. Permanent test points can be installed to simplify testing. Remember you want to sample the beginning middle and ends of your system to achieve balance in odor testing.

CONFIRMING ODORANT LEVELS

While the only method for testing odorant that insures safety is sniff testing, it is sometimes critical to confirm the level of odorant present in the natural gas that is being tested. This can be done using a device that can specifically determine the level of odorant present in natural gas

Using these sensors in a similar fashion as the sniff test devices a level of odorant in lbs/MMCF of natural gas can be determined. This concentration level can then be compared to the sniff test results to provide important information about the test location and additionally about the person conducting the sniff tests.

Figure 5; Portable Odorant Concentration Device

CONCLUSIONS

Natural gas has proven to be the fuel of the near future and the requirement for this safe, clean and relatively inexpensive fuel supply has given rise to various techniques of odorizing natural gas.

To implement a successful odorization system you must have a working knowledge of the chemical odorant used, and be aware of handling these chemicals so you can be a good neighbor in the community served. As important is the implementation of injection systems which will perform the critical job of odorant injection as well as provide real time information regarding system performance, alarm on failure and reporting of system history of operation.

We know that natural gas has no color or smell. For the safety of our homes, offices and schools you must odorize and then monitor those levels with a odorant level testing process that meets the regulatory mandates but more importantly provides the necessary information for maintaining a safe system. Then you must have a plan to include

- Become familiar and understand the requirements and mandates which deal with the odorization of natural gas.
- Develop a plan for the odorization process which includes the considerations of the specific odorant used, delivery and handling of the odorant, the injection of odorant into the pipeline, and testing for odor intensity.
- Within the plan evaluate and implement the requirements for safe and proper odorant delivery, handling accidents, the operational requirements of the odorant injection system application, and proper operation of intensity testing instruments.
- Include a plan for training of those operators who will work within the odorization process to insure their understanding of the process and the design and operation of the equipment used.
- Create and maintain a good record keeping system not only for the regulatory requirements, but for to increase the efficiency of the whole process.

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